

What is claimed is:

1. A method for determining a full match for a variable length search key by a computer processing device, comprising the acts of:
  - reading an input key as a search string;
  - hashing the input key using a hash function to generate a hashed key;
  - using the N most significant bits of the hashed key as an index into a table representing a plurality of root nodes of search trees wherein each non-empty entry contains a pointer to a next branch in the search tree or a leaf;
  - determining if the pointer in a non-empty table entry points to a leaf or a next branch of the corresponding search tree;
  - reading the next branch contents if the pointer does not point to the leaf of the corresponding search tree;
  - reading the leaf contents when the leaf of a corresponding search tree is reached and comparing a pattern in the leaf with the

hashed key to determine if the leaf pattern  
      matches the hashed key; and  
      returning the contents of the leaf found to the  
      requesting application if the leaf pattern  
      matches the hashed key.

2. The method for determining the full match of claim 1  
      wherein the table representing a plurality of root nodes  
      of search trees contains  $2^N$  entries.
3. The method for determining the full match of claim 1  
      wherein the computer processing device is a network  
      processor.
4. The method for determining the full match of claim 1  
      wherein the contents of the next branch of the  
      corresponding search tree points to another next branch.
5. The method for determining the full match of claim 1  
      wherein the contents of the next branch points to the  
      leaf of the corresponding search tree.

6. The method for determining the full match of claim 1 further comprising returning a no match found indication if the leaf pattern does not match the hashed key and does not contain a pointer to another leaf.
7. The method for determining the full match of claim 1 further comprising returning a no match found indication if the index into the table is to an empty entry.
8. The method for determining the full match of claim 1 further comprising appending the contents of a color register to the hashed key to provide a final hashed key.
9. The method for determining the full match of claim 1 further comprising appending a string of zeros to the hashed key to provide a final hashed key.
10. The method for determining the full match of claim 1 further comprising the act of terminating the search for the full match when the bit number of the next branch exceeds the length of the hashed key.

11. The method for determining the full match of claim 1 wherein the hash function used on the input key is a reversible hash function that can transform the hashed key into the input key.

12. The method for determining the full match of claim 1 further comprising the acts of:

if the leaf contains a chain pointer to another leaf, reading a pattern stored in another leaf and comparing the pattern with the hashed key; returning an indication of no match found if the pattern stored does not match the hashed key and does not contain a pointer to a next leaf in the chain.

13. The method for determining the full match of claim 1 further comprising the acts of:

if the leaf contains a chain pointer to another leaf, reading a pattern stored in another leaf and comparing the pattern with the hashed key; returning an indication of match found if the pattern stored does match the hashed key.

14. A computer readable medium containing a plurality of data structures for finding a full match for a variable length search key, comprising:

a pattern or key that is to be searched;

a direct table that stores a first address location for a search tree;

a plurality of pattern search control blocks that each represent a branch in the search tree;

and

a plurality of leaves wherein each leaf is an address location for the result of a search.

15. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 further comprising a lookup definition table that manages a tree search memory.

16. The computer readable medium containing a plurality of data structures for finding the full match of claim 15 wherein the lookup definition table comprises entries that define a physical memory that the tree resides in, a size of the key and leaf, and a type of search to be performed.

17. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 wherein the lookup definition table is implemented in a plurality of memories.
18. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 wherein a format for a direct table entry includes at least one of a search control block; a next pattern address that point to a next pattern search control block; a leaf control block address that points to a leaf or result; a next bit or bits to test; and a direct leaf.
19. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 wherein a format for a pattern search control block includes at least one of a search control block; a next pattern address that point to a next pattern search control block; a leaf control block address that points to a leaf or result; and a next bit or bits to test.

20. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 wherein a leaf data structure includes at least one of a leaf chaining pointer; a prefix length; a pattern to be compared to the search key; and variable user data.
21. The computer readable medium containing a plurality of data structures for finding the full match of claim 18 wherein the direct leaf is stored directly in a direct table entry and includes a search control block and a pattern to be compared to a search key.
22. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 wherein a pattern search control block is inserted in the search tree at a position where the leaf patterns differ.
23. The computer readable medium containing a plurality of data structures for finding the full match of claim 14 wherein a pattern search control block has a shape defined by a width of one and a height of one and is stored in a memory that has a line length of at least 36 bits.

24. An apparatus fabricated on a semiconductor substrate for determining a full match for a variable length search key, comprising:

an embedded processor complex including a plurality of protocol processors and an internal control point processor that provide frame processing;

a plurality of hardware accelerator co-processors accessible to each protocol processor and providing high speed pattern searching, data manipulation, and frame parsing;

a plurality of programmable memory devices that store a plurality of data structures that represent at least one search tree, wherein the data structures include a direct table, a pattern search control block and a leaf; and

an control memory arbiter that controls the access of each protocol processor to the plurality of memory devices.

25. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 24 further comprising a tree search engine that operates in parallel with protocol processor execution to perform tree search instructions including memory reads and writes and memory range checking.
26. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 24 wherein the plurality of memory devices further comprises at least one of internal static random access memory, external static random access memory, and external dynamic random access memory.
27. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 24 wherein the control memory arbiter manages control memory operations by allocating memory cycles between the plurality of protocol processors and the plurality of memory devices.

28. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 24 wherein each protocol processor comprises a primary data buffer, a scratch pad data buffer and control registers for data store operations.
29. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 24 further comprising a hash box component that performs a geometric hash function on the search key.
30. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 24 further comprising a programmable search key register and a programmable hashed key register.
31. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 30 further comprising a programmable color key register to enable sharing a single table data structure among a plurality of independent search trees.

32. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 31 wherein the contents of the color register, if enabled, are appended to the hash output to produce a final hashed key.
33. The apparatus fabricated on a semiconductor substrate for determining the full match of claim 31 wherein if the color register is not enabled, appending an equivalent number of zeros to the hash output to produce a final hashed key.
34. A computer readable medium containing a computer program product for determining a full match for a variable length search key, comprising:
  - program instructions that read an input key as a search string;
  - program instructions that hash the input key using a reversible hash function that can transform the hashed key into the input key;
  - program instructions that use the N most significant bits of the hashed key as an index into a table representing a plurality of root nodes of search trees wherein each non-empty

entry contains a pointer to a next branch in the search tree or a leaf;

program instructions that determine if the pointer in a non-empty table entry points to a leaf or a next branch of the corresponding search tree;

program instructions that read the next branch contents if the pointer does not point to the leaf of the corresponding search tree;

program instructions that read the leaf contents when the leaf of a corresponding search tree is reached and compare a pattern in the leaf with the hashed key to determine if the leaf pattern matches the hashed key; and

program instructions that return the contents of the leaf found to the requesting application if the leaf pattern matches the hashed key.

35. The computer program product for determining the full match of claim 34 wherein the table representing a plurality of root nodes of search trees contains  $2^m$  entries.

36. The computer program product for determining the full match of claim 34 wherein the computer processing device is a network processor.
37. The computer program product for determining the full match of claim 34 wherein the contents of the next branch of the corresponding search tree points to another next branch.
38. The computer program product for determining the full match of claim 34 wherein the contents of the next branch points to the leaf of the corresponding search tree.
39. The computer program product for determining the full match of claim 34 further comprising program instructions that return a no match found indication if the leaf pattern does not match the hashed key and does not contain a pointer to another leaf.
40. The computer program product for determining the full match of claim 34 further comprising program instructions that return a no match found indication if the index into the table is to an empty entry.

41. The computer program product for determining the full match of claim 34 further comprising program instructions that append the contents of a color register to the hashed key to provide a final hashed key.
42. The computer program product for determining the full match of claim 34 further comprising program instructions that append a string of zeros to the hashed key to provide a final hashed key.
43. The computer program product for determining the full match of claim 34 further comprising program instructions that terminate the search for the full match when the bit number of the next branch exceeds the length of the hashed key.

44. The computer program product for determining the full match of claim 34 further comprising:

program instructions that read a pattern stored in another leaf and compare the pattern with the hashed key if the leaf contains a chain pointer to another leaf;

program instructions that return an indication of no match found if the pattern stored does not match the hashed key and does not contain a pointer to a next leaf in the chain.

45. The computer program product for determining the full match of claim 34 further comprising:

program instructions that read a pattern stored in another leaf and compare the pattern with the hashed key if the leaf contains a chain pointer to another leaf;

program instructions that return an indication of match found if the pattern stored does match the hashed key.